

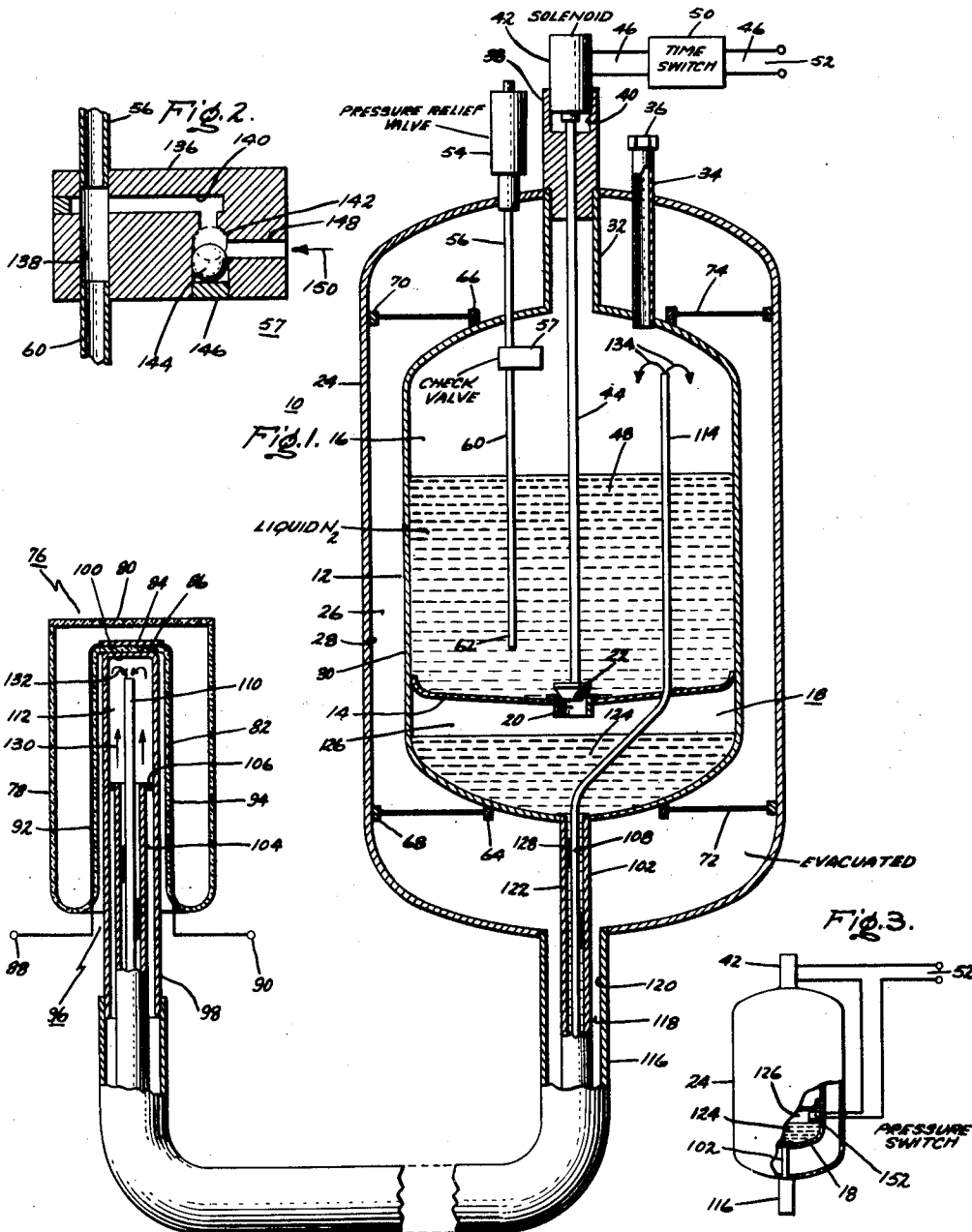
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K. L. DE BROSSÉ ET AL

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COOLING SYSTEM

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Inventors:
Kenneth L. DeBrosse,
Eugene Behun,
by *Lust & Dick*
Attorneys.

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Kenneth L. De Brosse and Eugene Behun, Fort Wayne, Ind., assignors to International Telephone and Telegraph Corporation

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This invention relates generally to cooling systems, and more particularly to a system employing liquid nitrogen for cooling certain electronic apparatus, such as radiation detectors, to very low temperatures.

Certain infrared detection devices require cooling for optimum operation. In the past, it has been common practice to provide such cooling with the so-called gas cryostat. The gas cryostat operates on the Joule-Thomson effect principle and commonly comprises a thin-wall conduit having a closed lower end and a low pressure gas discharge opening at its other end. Entering the conduit is a small elongated capillary tube extending downwardly generally in a "coiled coil" configuration and terminating in a small nozzle with nitrogen gas under high pressure being supplied to the tube from a container. Temperatures on the order of -196°C . are obtainable with a gas cryostat. Since the gas is customarily employed at a pressure on the order of 3,000 pounds per square inch, a pressure tank of extremely rugged construction to withstand the high pressures involved is obviously required. In addition, it has been found that there is a tendency for the capillary tubing and/or the nozzle to plug up, and additionally, some appreciable cool-down time is required with a gas cryostat.

It is desirable to provide a system particularly suited for cooling infrared detectors which employs liquid nitrogen rather than nitrogen gas as the coolant. Liquid nitrogen does not require the high pressure storage tank for nitrogen gas, thus providing a substantial reduction in the weight of the storage apparatus, and further, substantially greater cooling capacity is provided with liquid nitrogen in the same storage volume since a liter of liquid nitrogen contains on the order of three times as much nitrogen as a liter of nitrogen gas at 3,000 pounds per square inch. Furthermore, liquid nitrogen is at -196°C . and thus no cool-down time is required in a system employing liquid nitrogen.

It is accordingly an object of our invention to provide an improved cooling system.

Another object of our invention is to provide an improved cooling system employing liquid nitrogen as the coolant.

Our invention in its broader aspects provides a liquid nitrogen reservoir and a liquid nitrogen pressure chamber with valve means connecting the reservoir and the chamber for supplying liquid nitrogen thereto. A cooler is provided comprising a liquid nitrogen supply conduit connected to the pressure chamber and having a closed end remote therefrom and a liquid nitrogen return conduit having one end positioned in the supply conduit adjacent the closed end and having its other end positioned in the reservoir. In our system, therefore, liquid nitrogen under the influence of nitrogen gas pressure generated in the pressure chamber due to evaporation of the liquid nitrogen therein is forced through the supply conduit to the closed end thereof and is returned to the reservoir through the return conduit.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

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FIG. 1 is a diagram, partly in section and partly broken away, showing the cooling system of our invention;

FIG. 2 is a fragmentary cross-sectional view showing the check valve of the system of FIG. 1; and

FIG. 3 is a fragmentary schematic view showing a modification of the system of FIG. 1.

Referring now to FIG. 1, the cooling system of our invention, generally identified at 10, comprises a container 12 having a partition 14 thereacross defining an upper liquid nitrogen storage reservoir 16 and a lower liquid nitrogen pressure chamber 18. An opening 20 is centrally formed in partition 14 communicating between reservoir 16 and chamber 18 for admitting liquid nitrogen from the reservoir to the pressure chamber, opening 20 being normally closed by valve 22.

Container 12 is enclosed by envelope 24 spaced from container 12 with the space 26 therebetween being evacuated to form a Dewar flask. Preferably, the inner wall 28 of envelope 24 and the outer wall 30 of container 12 are silvered, as is well known in the art. Container 12 has a neck portion 32 connected to the wall of envelope 24 and providing access to the interior of reservoir 16, as shown. A filling tube 34 also extends through the walls of envelope 24 and container 12 for filling reservoir 16 with liquid nitrogen. Filling tube 34 is closed by a suitable closure 36.

A suitable sealing plug assembly 38 is positioned in neck portion 32 of container 12 extending on the outside of envelope 24 as shown. Plug member 38 has a recess 40 formed in its outer end which accommodates actuating solenoid 42. Valve stem 44 is provided extending downwardly from the solenoid 42 through the plug member 38, the neck portion 32 and reservoir 16 to the valve 22. Thus, when lines 46 connected to the operating coil (not shown) of solenoid 42 are energized by a suitable source of potential, solenoid 42 is actuated to raise valve stem 44 and thus open valve 22 to permit the liquid nitrogen 48 in reservoir 16 to flow through opening 20 into the pressure chamber 18. In the embodiment of FIG. 1, solenoid 42 is actuated by a suitable time switch 50 which periodically connects solenoid 42 to a suitable source of potential 52.

It will be understood that the liquid nitrogen 48 in reservoir 16 will evaporate at a rate dependent upon the heat transfer through the walls of envelope 24 and container 12, and the evacuated space 26 therebetween, and thus that nitrogen gas will accumulate in the space over liquid nitrogen 48, thus building up gas pressure. In order to relieve this gas pressure, we provide a pressure relief valve 54 having conduit 56 extending through the walls of envelope 24 and container 12 into the interior of reservoir 16. Check valve 57 is connected to conduit 56 in the interior of reservoir 16 over the normal level of the liquid nitrogen 48 when the device is in the upright position, as shown. As will be hereinafter more fully described in connection with FIG. 2, when the system is in the upright position as shown, check valve 57 admits the gas accumulating in the space in reservoir 16 over the liquid nitrogen 48 directly to conduit 56 and the pressure relief valve 54. However, if the system should become inverted, check valve 57 is actuated to connect conduit 60 to conduit 56 and pressure relief valve 54. It will be observed that the lower end of conduit 60 is normally immersed in the liquid nitrogen 48, however, if the system should become inverted, the lower end 62 of conduit 60 would then be exposed and would serve to vent the accumulated gas pressure to the atmosphere through pressure relief valve 54.

In order to support container 12 within envelope 24, we provide a pair of support rings 64 and 66 respectively engaging the top and bottom ends of container 12, rings 64 and 66 being respectively attached to support rings

63 and 70 mounted on the inner wall of envelope 24 by support wires 72 and 74.

In FIG. 1 there is shown a typical infrared detector 76 comprising an evacuated envelope 78 having its open end closed by a transparent window 80. Envelope 78 has a reentrant well 82 formed therein with infrared detector element 84 being mounted on its end wall 86. Detector 84 is connected to external leads 88 and 90 by conductive strips 92 and 94 on the inner wall of well 82, as shown. In order to provide for cooling infrared detector 76, we provide an elongated cooling element 96 adapted to extend into well 82 and to have its end engage end wall 86 so as to be in closest possible heat-transfer relationship to the detecting element 84. Cooling element 96 comprises a thin-wall conduit 98 having a closed end 100 adapted to engage end wall 86 of well 82; conduit 98 may be formed of any suitable high heat-transfer material, such as stainless steel. A liquid nitrogen conduit 102 is provided having one end communicating with liquid nitrogen pressure chamber 18 and having its other end 104 extending into cooler conduit 98 and connected to the wall thereof, as at 106. A liquid nitrogen return conduit 108 is provided coaxially disposed within the liquid nitrogen supply conduit 102 having one end 110 extending out of the supply conduit 104 into space 112 of cooler conduit 98 adjacent closed end 100 and having its other end 114 extending through liquid nitrogen pressure chamber 18 and partition 14 into reservoir 16 above the normal level of the liquid nitrogen 48 therein. An outer sleeve 116 is coaxially disposed over supply conduit 102 having one end connected to envelope 24 and having its other end connected to cooler conduit 98, as shown. The space 118 between sleeve 116 and supply conduit 102 communicates with the interior of envelope 24 and is thus evacuated. The inner surface 120 of sleeve 116 and the outer surface 122 of supply conduit 102 are also preferably silvered.

In the operation of the system shown in FIG. 1, time switch 50 energizes solenoid 42, thereby to open valve 22 and to permit liquid nitrogen to be admitted through opening 20 into pressure chamber 18 from reservoir 16. Time switch 50 permits a suitable quantity of liquid nitrogen 124 to enter pressure chamber 18 and thereafter de-energizes solenoid 42 to close valve 22. Evaporation of the liquid nitrogen 124 in pressure chamber 18 generates nitrogen gas in the space 126 over liquid nitrogen 124, the accumulated nitrogen gas pressure forcing the liquid nitrogen 124 through the supply conduit 102, as shown by arrows 128, into end 112 of cooler conduit 98, as shown by arrows 130. The aforementioned nitrogen gas pressure in space 126 over liquid nitrogen 124 in pressure chamber 18 further causes the liquid nitrogen forced into end 112 of cooler conduit 98 to enter end 110 of liquid nitrogen return conduit 108, as shown by arrows 132 and thus to be returned to reservoir 16, as shown by arrows 134. The resultant circulation of liquid nitrogen through end 112 of thin-wall cooler conduit 98 extracts heat from detector element 84 of the infrared detector 76. Time switch 50 thereafter again energizes solenoid 42 to open valve 22 to admit further liquid nitrogen from reservoir 16 into chamber 18 in order to continue the circulation of liquid nitrogen under the influence of the nitrogen gas pressure in space 126 over liquid nitrogen 124 in chamber 18 through supply conduit 102 into end 112 of cooler conduit 98 and back through liquid nitrogen return conduit 108 into reservoir 16.

Referring now to FIG. 2, check valve 57 comprises a body 136 having a passage 138 therein with which conduits 56 and 60 communicate. A transverse passage 140 communicates with passage 138 and an opening 142 communicates with the end of passage 140 remote from passage 138. A suitable ball 144 is positioned in opening 142 which is closed by a plug member 146. Port 148 in turn communicates with opening 142, as shown. It will be readily apparent that with the check valve 57 in the

upright position shown in FIGS. 1 and 2, ball 144 under the influence of gravity will be seated upon plug 146, thus allowing port 148 to communicate with passage 140. Since the lower end 62 of conduit 60 is, under these conditions, submerged in the liquid nitrogen 48, the nitrogen gas accumulated over liquid nitrogen 48 will enter port 148, as shown by arrow 150, and pass through opening 148 and passage 140 into conduit 56. However, if the system is inverted, it will be seen that the ball 144 will, under the influence of gravity, fall to the position shown in dashed lines in FIG. 2, thereby closing opening 142 so that port 148 no longer communicates with passage 140. Under these conditions, end 62 of conduit 60 is no longer submerged, but rather is exposed to the accumulated nitrogen gas over liquid nitrogen 48 so that the nitrogen gas is thus vented to the pressure relief valve 54 through conduit 60, passage 138 and conduit 56.

Referring now to FIG. 3, while the periodic energization of solenoid 42 by time switch 50 is found to be entirely satisfactory since the rate of transfer of liquid nitrogen from pressure chamber 18 through supply conduit 102, cooler conduit 98 and return conduit 108 back to reservoir 16 is readily determined, it may be desirable to provide a pressure switch 152 located in chamber 18 over the normal level of liquid nitrogen 124, pressure switch 152 being connected to energize solenoid 42 from source 52. Pressure switch 152 thus senses the nitrogen gas pressure in space 126 over liquid nitrogen 124 thereby energizing solenoid 42 to open valve 22 and in turn to admit further liquid nitrogen from reservoir 16 to pressure chamber 18 responsive to a predetermined nitrogen gas pressure level in the space 126.

A system as shown in FIG. 1 which accommodated one liter of liquid nitrogen had a total weight of approximately eight (8) pounds and was operated continuously for a period of twenty-four hours before the supply of liquid nitrogen was exhausted through evaporation. By contrast, a gas cryostat system employing five hundred cubic inches of nitrogen gas under 3,000 pounds per square inch pressure weighed fifty pounds and was only capable of continuous operation for two hours.

It will now be readily seen that we have provided an improved cooling system particularly suited for cooling radiation detectors to very low temperatures which is superior to the prior gas cryostat arrangements since it provides cooling to the same low temperature, i.e., -196° but involves far less overall weight and provides cooling for a far longer time with a minimum cool-down period.

While we have described above the principles of our invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of our invention.

What is claimed is:

1. A cooling system comprising: a liquid nitrogen reservoir; a liquid nitrogen pressure chamber; valve means connecting said reservoir and chamber for supplying liquid nitrogen thereto; and a cooler comprising a liquid nitrogen supply conduit connected to said chamber and having a closed end remote therefrom, and a liquid nitrogen return conduit having one end positioned in said supply conduit adjacent said closed end and having its other end positioned in said reservoir whereby liquid nitrogen under the influence of nitrogen gas pressure generated in said chamber due to evaporation of the liquid nitrogen therein is forced through said supply conduit to said closed end thereof and returned to said reservoir through said return conduit said cooling system further comprising a pressure relief valve positioned outside of said reservoir, a first pressure relief conduit connected to said pressure relief valve and extending into said reservoir, a check valve connected to said first relief conduit and positioned so as to be above the normal level of liquid nitrogen in said reservoir, and a second pressure relief conduit communicating with said first relief conduit and

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extending below the normal level of liquid nitrogen in said reservoir, said check valve having a pressure relief port normally communicating between said reservoir and said first relief conduit whereby nitrogen gas generated in said reservoir due to evaporation of liquid nitrogen therein is vented to the atmosphere through said port, first relief conduit and relief valve when said system is in a normal position, said check valve having valve means for closing said port due to inverting of said system from said normal position whereby said nitrogen gas in said reservoir is vented through said second and first relief conduits and said relief valve.

2. A cooling system comprising: a liquid nitrogen reservoir; a liquid nitrogen pressure chamber; valve means connecting said reservoir and chamber for supplying liquid nitrogen thereto; a cooler comprising a conduit with a closed end; a liquid nitrogen supply conduit communicating between said cooler and said chamber; and a liquid nitrogen return conduit communicating between said cooler and said reservoir pressure control means connected to said reservoir and adapted to maintain the vapor pressure of said nitrogen in said reservoir at a lower pressure than the pressure in said pressure chamber whereby liquid nitrogen under the influence of nitrogen gas pressure generated in said chamber due to evaporation of the liquid nitrogen therein is forced through said supply conduit to said cooler and returned to said reservoir through said return conduit.

3. The combination of claim 2 wherein said return conduit is concentric within said supply conduit.

4. A cooling system comprising: a liquid nitrogen reservoir; a liquid nitrogen pressure chamber; a passage communicating between said reservoir and chamber; a valve normally closing said passage and being selectively operable to open the same for supplying liquid nitrogen from said reservoir to said chamber; electrically energizable solenoid means outside of said reservoir and chamber operably connected to said valve; and a cooler comprising a liquid nitrogen supply conduit connected to said chamber and having a closed end remote therefrom, and a liquid nitrogen return conduit having one end positioned in said supply conduit adjacent said closed end and having its other end positioned in said reservoir whereby liquid nitrogen under the influence of nitrogen gas pressure generated in said chamber due to evaporation of the liquid nitrogen therein is forced through said supply conduit to said closed end thereof and returned to said reservoir through said return conduit said cooling system further comprising means for energizing said solenoid at predetermined time intervals thereby to operate said valve to admit liquid nitrogen to said chamber.

5. A cooling system comprising: a Dewar flask having an inner container and an outer envelope spaced from said container with the space therebetween being evacuated, said container having a neck portion joined to said envelope, said container having a partition extending thereacross and defining an upper liquid nitrogen reservoir and a lower liquid nitrogen pressure chamber, said partition having an opening therethrough communicating between said reservoir and said chamber; a valve normally seated in said opening for closing the same; means closing said neck portion and having an electrically energizable solenoid thereon; a valve stem connecting said solenoid to said valve and extending through said closing means, neck portion and reservoir for opening said valve responsive to energization of said solenoid thereby to admit liquid nitrogen from said reservoir to said chamber; a cooler comprising an elongated conduit formed of thin-wall, high heat-conductive material and having a closed end, an elongated liquid nitrogen supply conduit having one end communicating with said cooler conduit and its other end extending through said outer envelope and communicating with said chamber; a liquid nitrogen return conduit coaxial within said supply con-

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duit having one end extending into said cooler conduit and its other end extending through said partition and into said reservoir over the normal level of liquid nitrogen therein whereby liquid nitrogen under the influence of nitrogen gas pressure generated in said chamber due to evaporation of the liquid nitrogen therein is forced through said supply conduit into said cooler conduit and returned to said reservoir through said return conduit; and a sleeve surrounding said supply conduit and spaced therefrom, said sleeve having an end closed adjacent said cooler and having its other end joined to said envelope and communicating therewith so that said sleeve is evacuated with said envelope.

6. A cooling system comprising a liquid nitrogen reservoir; a liquid nitrogen pressure chamber; valve means connecting said reservoir and chamber for supplying liquid nitrogen thereto; a cooler comprising a conduit with a closed end; a liquid nitrogen supply conduit communicating between said cooler and said chamber; and a liquid nitrogen return conduit communicating between said cooler and said reservoir whereby liquid nitrogen under the influence of nitrogen gas pressure generated in said chamber due to evaporation of the liquid nitrogen therein is forced through said supply conduit to said cooler and returned to said reservoir through said return conduit, said reservoir and said chamber being enclosed within a first envelope with said supply and return conduits extending therethrough and the portion of said supply and return conduits extending from said first envelope being enclosed within a sleeve communicating with said first envelope, said envelope and sleeve being evacuated to form a Dewar flask.

7. A cooling system comprising a liquid nitrogen reservoir; a liquid nitrogen pressure chamber; a passage communicating between said reservoir and chamber; a valve normally closing said passage and being selectively operable to open the same for supplying liquid nitrogen from said reservoir to said chamber; electrically energizable solenoid means outside of said reservoir and chamber operably connected to said valve; and a cooler comprising a liquid nitrogen supply conduit connected to said chamber and having a closed end remote therefrom, and a liquid nitrogen return conduit having one end positioned in said supply conduit adjacent said closed end and having its other end positioned in said reservoir whereby liquid nitrogen under the influence of nitrogen gas pressure generated in said chamber due to evaporation of the liquid nitrogen therein is forced through said supply conduit to said closed end thereof and returned to said reservoir through said return conduit, said cooling system further comprising pressure sensing means in said chamber for sensing the gas pressure therein and switch means actuated by said pressure sensing means and connected to energize said solenoid responsive to a predetermined gas pressure in said chamber.

8. A cooling system utilizing solely the vapor pressure of a liquid coolant to provide circulation of the coolant in a closed path, said system comprising a liquid coolant reservoir, a liquid coolant pressure chamber, means connecting said reservoir and said pressure chamber by two paths, each path consisting solely of passive fluid conducting members with a valve inserted in one of said paths, said valve normally closing said member and being selectively operable to open said member for supplying liquid coolant from said reservoir to said chamber, said second path comprising a closed return path between said pressure chamber and said reservoir including a liquid coolant supply conduit connected to said pressure chamber and having a closed end remote therefrom and a liquid coolant return conduit having one end positioned in said supply conduit adjacent said closed end and having its other end positioned in said reservoir whereby liquid coolant under the influence of the vapor pressure of said liquid coolant generated in said pressure chamber due to evaporation of the liquid coolant therein is forced

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through said supply conduit to said closed end thereof and returned to said reservoir through said return conduit by said vapor pressure.

9. A cooling system according to claim 8 further comprising pressure control means connected to said reservoir and adapted to maintain the vapor pressure of said liquid coolant in said reservoir at a lower pressure than the pressure in said pressure chamber.

10. A cooling system according to claim 8 further comprising electrically energizable solenoid means outside of said reservoir and chamber operably connected to said valve, and means for energizing said solenoid at predetermined time intervals thereby to operate said valve to admit liquid coolant to said pressure chamber.

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11. A cooling system according to claim 10 further comprising pressure sensing means in said pressure chamber for sensing the gas pressure therein and switch means actuated by said pressure sensing means and connected to energize said solenoid responsive to a predetermined vapor pressure in said chamber.

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